

ANALYSIS OF RADIATION EXPOSURE FOR OBSERVERS AND MANEUVER TROOPS

Exercise Desert Rock IV, Operation Tumbler-Snapper

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Technical Report

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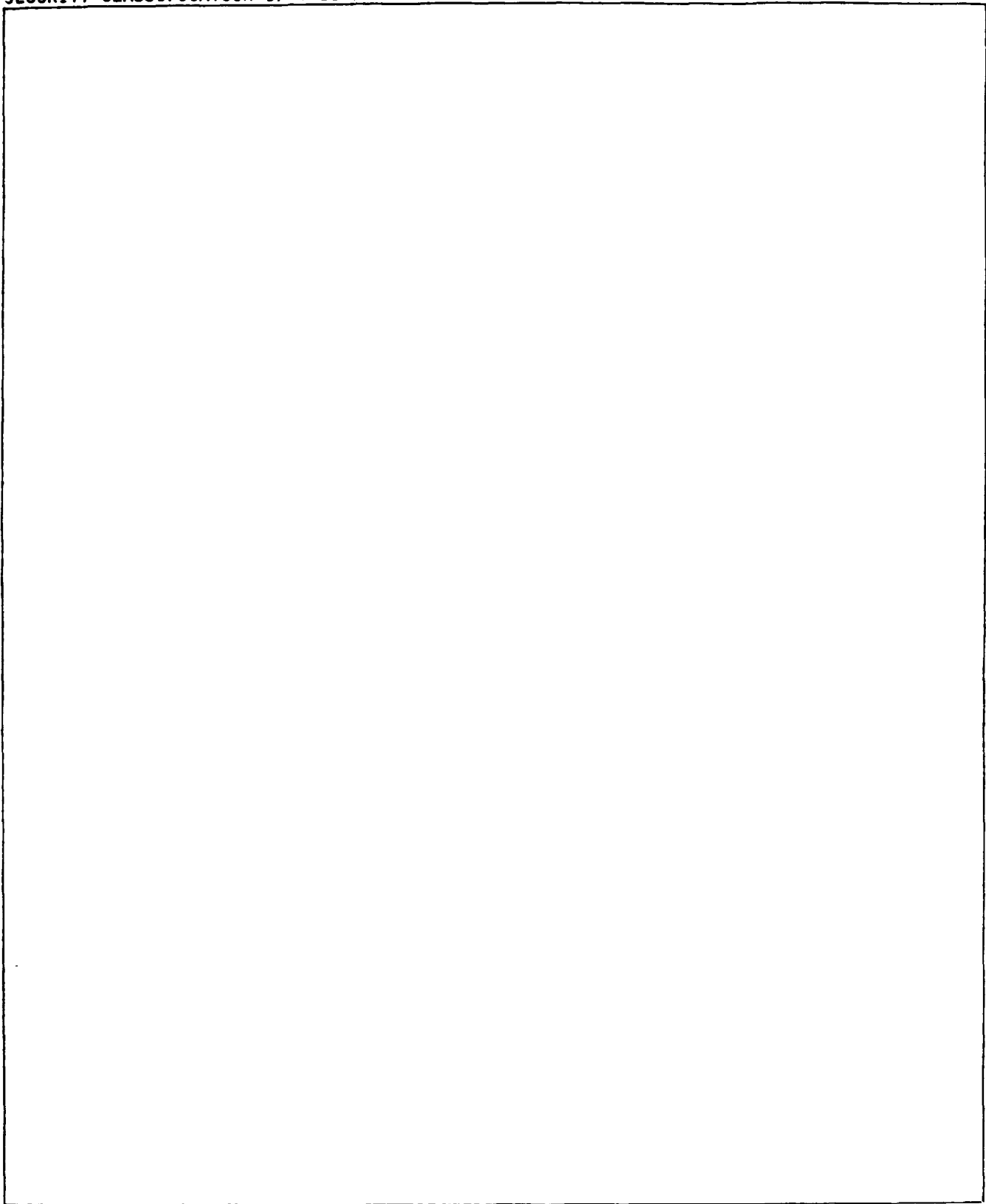
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19 ABSTRACT (Continue on reverse if necessary and identify by block number) The radiation doses to observers and maneuver units for Exercise Desert Rock IV are reconstructed for each applicable shot of Operation Tumbler-Snapper (1952). Residual radiation doses are calculated by using an automated procedure to couple scenarios for troop activities to the radiation environment. Uncertainties are determined for each parameter. Possible exposure to initial radiation and internal doses are also assessed. The calculated film badge equivalent doses range from 11 mrem (paratroop units, Shot Charlie) to 370 mrem (maneuver troops, Shot Dog). Initial doses were negligible for all participants at all shots.				
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SECTION 1

INTRODUCTION

This report is an analysis of the nuclear radiation exposure for military participants in the 1952 series of nuclear tests at the Nevada Proving Ground (NPG) (presently called the Nevada Test Site). The series was designated Operation Tumbler-Snapper.

Operation Tumbler-Snapper consisted of 8 shots (Figure 1), detonated over a period of nine weeks in the spring of 1952. Exercise Desert Rock IV, conducted in conjunction with Operation Tumbler-Snapper, consisted of military activities at four of the tests, Charlie, Dog, Fox, and George.

There were three types of military participation in Exercise Desert Rock IV. The first consisted of troop observers, who were military personnel sent to Camp Desert Rock for the specific purpose of observing one or more nuclear shots. Troop observers participated in Shots Charlie, Dog, Fox, and George.

The second type of military participation consisted of battalion-size maneuver units that moved to Camp Desert Rock for the purpose of engaging in tactical exercises to test doctrine and tactics being developed for the nuclear battlefield. Two such exercises were conducted: an Army Battalion Combat Team (BCT) and two Provisional Air Force Squadrons maneuvered at Shot Charlie and a Marine Corps Provisional Exercise Unit maneuvered at Shot Dog.

Third, there were the personnel assigned to Camp Desert Rock, usually for the entire exercise, who planned, supported, and administered the overall exercise. Some of these support elements participated in shots as observers or maneuver units, e.g., the Army Engineer Amphibious Support Regiment that was assigned to Camp Desert Rock also maneuvered at Shot George. Some Camp Desert Rock support personnel also witnessed Shots Able, Baker, and Easy, but from a great distance; these activities were not part of Exercise Desert Rock IV.

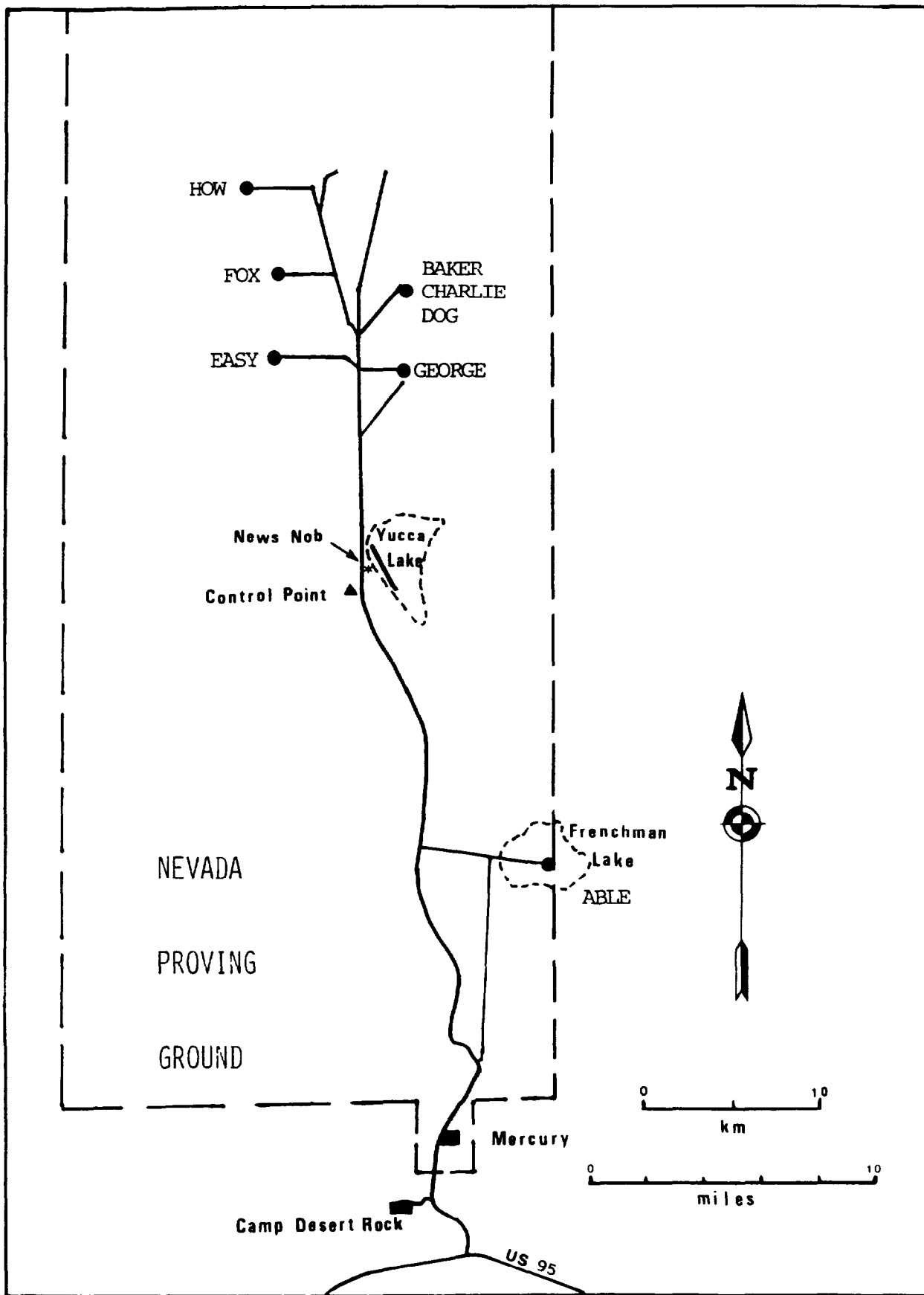


Figure 1. Shot locations, Operation Tumbler-Snapper.

It should be noted that a fourth major category of military participation, not a part of Exercise Desert Rock, consisted of projects conducted under the sponsorship of Field Command, Armed Forces Special Weapons Project. These efforts, as well as the support provided by Department of Defense personnel to other test groups and to the overall operation, are to be analyzed as necessary to supplement available film badge dosimetry.

Activities for each of the shots are traced from the pre-shot orientation through the shot activities, including any tactical maneuver and post-shot equipment inspection. Time-dependent position information is presented in order that an exposure analysis can be performed to determine the integrated dose from all contributing sources, principally the external dose due to residual radiation from the shot and applicable preceding shots.

The analysis utilizes an automated procedure, developed previously (Reference 2) for determining the external dose due to residual radiation. Radiological survey data are fit, in statistical regression analyses, to space-time models of residual radiation intensity, from which isointensity contours (isopleths) are then developed.

As in previous reports, the methodology also considers the effect of soil activation in the residual radiation analysis. This is particularly important for Shots Charlie and Dog, where the residual contamination of the post-shot times of interest was primarily due to the neutron-induced activity of Manganese-56 and Sodium-24. For some other shots, the induced contribution was evident near ground zero, but at greater distances it was small compared to the contribution from fission products. In all cases, the decay model is representative of actual shot conditions, verified by correlations with available data.

Comparison is made between calculated dose and available film badge records. The methodology for determining personnel dose is essentially that used in previous analyses (References 2, 26, and 27), in which comparisons with dosimetric data established a high degree of confidence. The uncertainties in the results are due primarily to the uncertainties in both the radiological surveys and the time-position

descriptions of troop activities. Automation of the dose estimation procedure facilitates the determination of confidence levels and aids in subsequent exposure analyses of other troop operations in the same radiologically contaminated areas.

The major finding of this report is that the radiation doses for Exercise Desert Rock IV participants ranged from 11 mrem (Shot Charlie, paratroop unit) to 370 mrem (Shot Dog participants). All calculated doses are from residual radiation and are significantly less than the 3 rem maximum dose permitted for Exercise Desert Rock IV.

SECTION 2 OPERATIONS

2.1 SHOT DATA.

A summary of the eight test shots of Operation Tumbler-Snapper is contained in Table 1. To determine radiation exposure for participants, all shots are considered for any residual radiation that might have contributed to total radiation dose.

2.2 PARTICIPATION.

Exercise Desert Rock IV maneuver and observer troops consisted of an estimated 7,700 military personnel who arrived at Camp Desert Rock to participate in testing and training programs. These troops, unlike the Camp Desert Rock support troops, were assigned to Camp Desert Rock to participate in specific activities associated with a particular shot. These activities included the troop observer program and tactical troop maneuvers, both of which are treated in this report.

2.2.1 Observers.

There were three categories of observer personnel participating in Exercise Desert Rock IV. In addition, other military and civilian observers, sponsored by the Atomic Energy Commission or the Armed Forces Special Weapons Project, witnessed shots but generally did not participate in shot activities to the same extent as did Exercise Desert Rock personnel. The categories of Desert Rock observers were as follows:

Service Observers. This group consisted of personnel selected from all four military services. They were sent to Camp Desert Rock from military bases throughout the United States, as well as from some overseas areas, to become familiar with nuclear weapons and their effects. They usually observed a shot from the same location as maneuver troops (7000 yards from ground zero) and inspected the resulting damage to equipment exposed to the shot. The

Table 1. Shot data, Operation Tumbler-Snapper.

SHOT DESIGNATION		DATE Actual (Sched)	LOCAL TIME (PDT)*	LOCATION COORDINATES (UTM)	BURST HEIGHT** (ft)	YIELD (KT)
AEC	DESERT ROCK					
ABLE	IV-1	1 April (1 April)	0900 (PST)	Frenchman Lake 950729	793 A	1
BAKER	IV-2	15 April (15 April)	0930 (PST)	Area 7 872044	1,109 A	1
CHARLIE	IV-3	22 April (22 April)	0930 (PST)	Area 7 871045	3,447 A	31
DOG	IV-4	1 May (29 April)	0930	Area 7 871044	1,040 A	19
EASY	IV-5	7 May (6 May)	0515	Area 1 798009	300 T	12
FOX	IV-6	25 May (13 May)	0500	Area 4 795056	300 T	11
GEORGE	IV-8	1 June (20 May)	0455	Area 3 871004	300 T	15
HOW	IV-7	5 June (27 May)	0455	Area 2 784104	300 T	14

*Unless noted as Pacific Standard Time (PST)

**T = Tower, A = Air Drop

Source:
References 6, 7, 8

participation of the service observers is shown in Table 2. It should be noted that, due to possible participation in more than one shot, the numbers in each category are not necessarily additive. This is explained in Section 2.3. It should also be noted that the service observers did not engage in any maneuvers or other similar exercises while at Nevada Proving Ground.

Camp Desert Rock (CDR) Observers. This group consisted of Army personnel assigned to Camp Desert Rock as the permanent party--that is, those who planned, administered, and supported the maneuvers and programs (including the observer program) that comprised Exercise Desert Rock IV. They were permitted to observe one or more shots during their stay at Camp Desert Rock, but most likely not one of the four shots at which Desert Rock exercises were conducted.

Civilian Observers. These observers were apparently civil service employees from the various army areas who were sent to Camp Desert Rock in the same manner as other military service observers. Their number is unknown. There were many other civilian observers at NPG, not sponsored by Desert Rock, who participated in various shot-related activities.

2.2.2 Maneuver Troops.

Approximately 4,900 exercise troops took part in the tactical maneuvers conducted at Shots Charlie, Dog, and George. Units from the Army, Marine Corps, and Air Force traveled to NPG specifically to participate in the maneuvers. In addition to these personnel, Camp Desert Rock support troops were utilized to form the maneuver elements for Shot George. Table 3 gives the total number of participants in the maneuvers at each shot.

2.3 CONCEPT.

The purpose of Exercise Desert Rock IV was to provide indoctrination and training in military operations involving tactical employment of nuclear weapons; to

Table 2. Observer participation, Exercise Desert Rock IV.

Shot	Army	Navy	Marine Corps	Air Force	Total ⁺ Observers
CHARLIE	300			200	500
DOG		50*	300*		350*
FOX	1450				1450
GEORGE	550 (est.)				550 (est)

*References report a total of 350 personnel from the Navy and Marine Corps. The breakdown by individual service is an estimate.

+Does not include an unknown number of DoD personnel who observed the tests but not as part of Exercise Desert Rock.

Source: References 1, 6, 7, 9

Table 3. Maneuver troop participation, Exercise Desert Rock IV.

<u>Participating Service</u>	<u>CHARLIE</u>	<u>DOG</u> ^{Shot}	<u>FOX</u>	<u>GEORGE</u>
Army	700			
Marine Corps		1950		
Air Force	325			
Camp Desert Rock Support Troops (Army)	500			1400
	<hr/>	<hr/>		<hr/>
Total Participants	1525	1950		1400

Source: References 4, 7, 9, 10, 11

demonstrate to participating maneuver troops and observers the effects of nuclear explosions on prepared positions and equipment; to determine psychological reactions of participating troops; and to determine the type and amount of indoctrination in nuclear warfare required for all personnel.

In general, Exercise Desert Rock IV was a continuation of the military exercises conducted in conjunction with Operation Buster-Jangle. For Operation Tumbler-Snapper, the US Army was given substantial responsibility for radiological safety of participating Desert Rock IV personnel. The Desert Rock IV operation plans provided for witnessing the shots from closer distances than in previous exercises while allowing participants to conduct somewhat realistic military exercises within radiation limits. Subject to radiation constraints, troop maneuvers were allowed near ground zero as long as there was no interference with instrumentation or other experiments.

Observers and maneuver troops generally participated together in activities that included the following:

- o Pre-shot classroom instruction.
Subjects included basic nuclear theory, characteristics and effects of nuclear weapons, protective measures to employ against a nuclear attack, tactical use of nuclear weapons, and a plan of operation for the upcoming shot. Eight hours of instruction were planned. For those observers who did not arrive at Camp Desert Rock in time for the instruction, a one-hour orientation was conducted on the evening preceding the shot.
- o Rehearsal of shot day activities.
Observers visited the trenches, had a "dry run" of the detonation, and then viewed the display area established for the shot. In some cases, they were taken to the display area of a previous test to see the post-shot effects. Maneuver troops rehearsed their activity and then viewed the display area.
- o Shot observation.
Approximately one hour before the scheduled shot, observers arrived at the trench area, were briefed on what to expect, and were checked for proper

safety procedures. A few minutes before the shot, they entered the trenches and assumed a crouching position.

- o Guided tour through display area.

Under the direction of the Desert Rock control group, observers toured the equipment display area to see and have explained the effects of the detonation on animals, equipment, and prepared positions.

In addition, the maneuver troops participated in a tactical maneuver involving an attack on an objective in accordance with the exercise plans. The troops were accompanied by radiological safety monitors and preceded by radiological survey teams who determined the limits of safe advance. After reaching their objective or approaching as close as radiation safety standards would permit, the maneuver was terminated. Under the direction of the Desert Rock control group, the troops would then inspect the display area. After they viewed the display areas, both maneuver troops and observer groups returned to Camp Desert Rock.

For radiological safety purposes, a maximum permissible dose of 3 rem was established for the entire exercise (Reference 1). The 500 mr/hr intensity line was the limit of advance for the troops unless otherwise authorized by the Commanding General, Camp Desert Rock. Standard operating procedures for radiological safety in all operations were based on these criteria.

Film badges were to be issued to all participants the day before the shot and collected on shot day. Shortly after the passage of the shock wave, Army rad-safe monitors were to precede the troops and survey the contaminated area. Unless otherwise noted, observer and maneuver activities in the shot area would begin with the completion of the surveys and the declaration of recovery hour (R-hour) by the AEC. Before leaving the forward area, participants and vehicles were to be brushed with brooms and then monitored (usually at the parking area) to ensure compliance with radiation limits. Any person or vehicle with radiation intensity greater than 10 mr/hr was to be sent to the decontamination station at Yucca Pass. Personnel sent to Yucca Pass were to shower and put on clean clothes; all vehicles were to be washed.

On return to Camp Desert Rock, all personnel were to shower and put on clean clothing and were then to be monitored to ensure compliance with limits of 1.5 mr/hr for clothing, and 0 mr/hr for skin. All contaminated vehicles were to be decontaminated to background count. (References 1, 12).

2.4 ACTIVITIES.

Shot data for Operation Tumbler-Snapper are listed in Table 1. Weather or technical difficulties altered the general schedule in several of the shots. For all shots, participants departed Camp Desert Rock for the trench area in convoys of buses and trucks. All participants occupied the same set of trenches at a given shot. When a unit made a post-shot inspection of equipment displays, movement to and through the display area was normally accomplished as a single group. Ground zero locations, the trench locations, and the display areas are identified on the figures accompanying the discussion of each shot. The following paragraphs describe the activities for each shot.

2.4.1 Shot Charlie.

Observers. Observers for Shot Charlie consisted of approximately 300 Army personnel from the six continental armies and military service schools and approximately 200 Air Force personnel (Reference 9). Most observers reported for duty between 18 and 21 April (Reference 13). Observers were integrated with troop units in indoctrination and in witnessing the explosion (Reference 1).

On 19 April, three days before the shot, observers rehearsed their shot-day activities, proceeding into the trenches and inspecting the equipment display areas. From 19 to 21 April, the Instructor Group used films and lectures to familiarize the observers with the characteristics of a nuclear detonation and safety procedures to follow during a nuclear test (Reference 13).

At about 0500* hours on shot day, observers began leaving Camp Desert Rock by motor convoy for the trench area. All observers were in the trench area by 0816 hours (References 1, 14). At about an hour before the shot, a Camp Desert Rock instructor conducted a final briefing, describing shot time procedures and safety precautions. Ten minutes before the shot, all personnel were ordered into the trenches and foxholes, 7000 yards south of the intended ground zero (see Figure 2). Two minutes before the 0930 shot, the Exercise Director ordered all participants to crouch, cover their faces with their hands, and lean against the forward wall of the trenches. Three seconds after the flash, the troops were allowed to stand and observe the rising fireball. About 15 seconds later, the shock wave reached the trench area, temporarily obscuring vision. About 25 minutes later, Army rad-safe monitors moved forward to survey the contaminated area (Reference 1). The observers remained in the trench area while the survey was conducted (Reference 13). At 1027 hours, recovery hour was declared by the AEC (Reference 15), and at 1030 hours observers boarded trucks and moved into the shot area (Reference 1). The convoy traveled north on to BJY and proceeded to parking area F, stopping to unload the troops about 3500 yards from GZ (Reference 13). The observers began their tour of the equipment display area on foot at about 1100 hours, advancing to each display and stopping to observe the effects of the explosion. The equipment displays were located at 3500, 1700, 900, 550 and 200 yards from ground zero, as shown in Figure 2 (Reference 1). The observers reached the 200-yard display area at approximately 1215 hours. They then returned to the vehicle parking area and were monitored for contamination. At approximately 1330 hours, the observers boarded their vehicles and left for Camp Desert Rock, where they arrived at about 1530 hours.

Maneuver Units. Maneuver units for Shot Charlie consisted of an Army battalion combat team (BCT) and two Air Force squadrons, made up of approximately 1525 troops as follows:

*All times for Shot Charlie are Pacific Standard Time (PST)

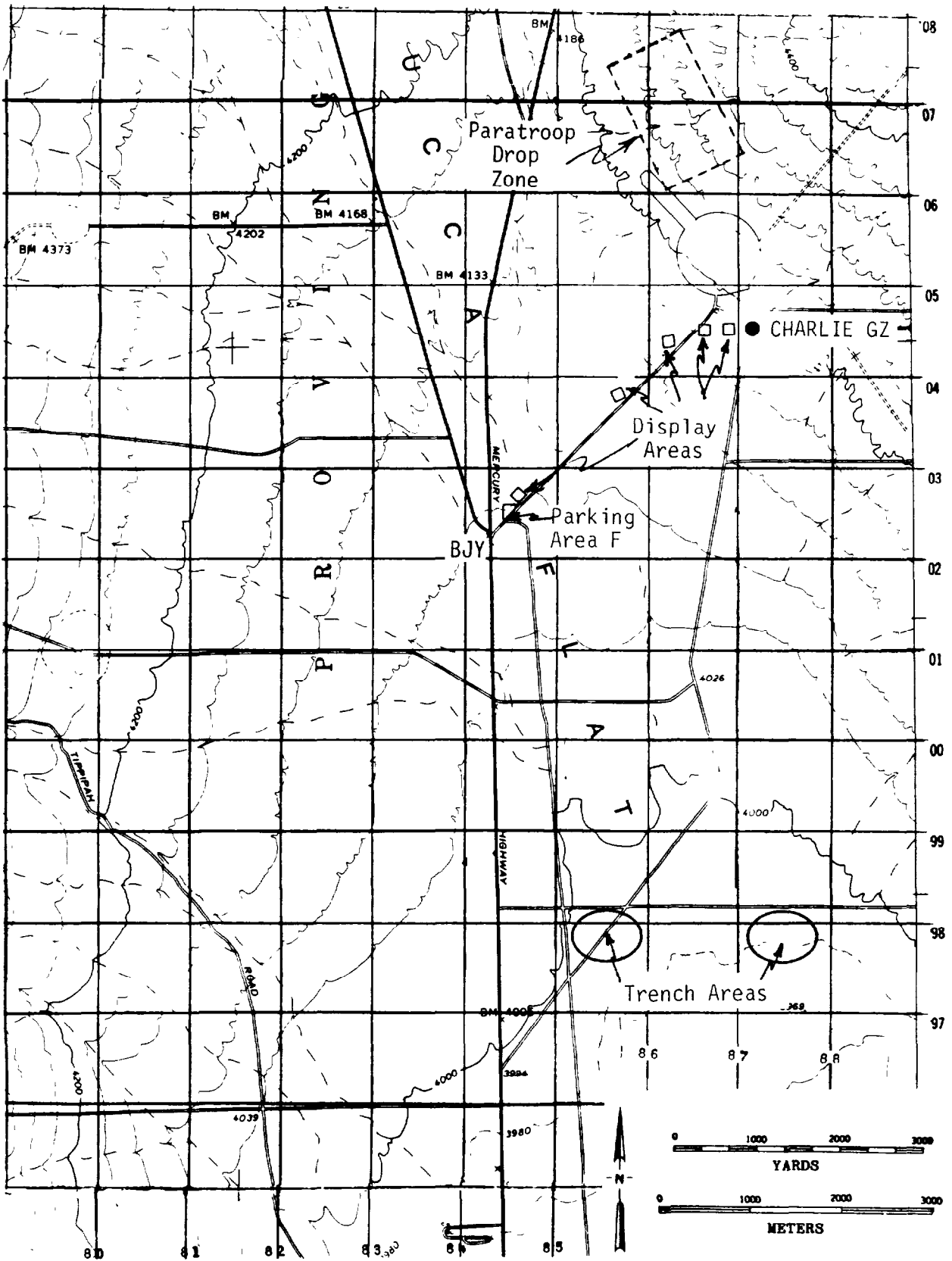


Figure 2. Shot Charlie area.

Company F, 504th Regiment, 82d Airborne Division
Company H, 504th Regiment, 82d Airborne Division
Company B, 165th Infantry Regiment, 31st Infantry Division
Company C, 135th Infantry Regiment, 47th Infantry Division
1 Tank Platoon, 11th Armored Cavalry (tanks provided by Camp Irwin)
1 Engineer Platoon, 369th Engineer Amphibious Support Regiment (EASR)
1 Medical Detachment, 369th EASR (augmented from Sixth Army)
Approximately 400 additional troops from the 369th EASR
(References 10, 11, 13, and 16)

The two Air Force squadrons were made up as follows:

187th Provisional Fighter-Bomber Squadron (comprised of personnel from the 140th Fighter-Bomber Group, the 140th Wing Headquarters and Headquarters Squadron, and the 140th Medical Group).

140th Provisional Maintenance Squadron (comprised of personnel from the 140th Maintenance and Supply Group and the 140th Air Base Group).
(Reference 17)

Maneuver elements reported to Camp Desert Rock by 18 April (Reference 13). From their arrival at Camp Desert Rock until they reached the 200-yard equipment display on their post-shot tour, the maneuver troop activities were the same as the observer activities, except for the paratroops (Company F, 504th Airborne Infantry Regiment), and tank crews, whose activities are described below.

Tank crews remained inside their tanks at the trench area (there is no record of a tank maneuver). The paratroops, numbering approximately 110-120 (Reference 11), were with the ground forces in the trench area for the detonation. Immediately after the shot, the paratroops loaded onto trucks and proceeded south to the Yucca Flat landing strip (Reference 15). They boarded several C-46 aircraft, which took off at 1050 hours (about 20 minutes after R-hour) for the ground zero area. A C-47 hospital aircraft accompanied the C-46 aircraft (References 17, 18). The planes took off to

the southeast and made a large clockwise circle until they lined up with the drop zone northwest of ground zero. (The drop zone had presumably been declared radiologically safe for Desert Rock purposes by Army rad-safe monitors who accompanied AEC initial rad-safe survey teams.) The paratroops were supposed to begin parachuting at about 1115 hours into the drop zone shown in Figure 2 (References 15, 18). However, the paratroops in one C-46 jumped four minutes early and landed as far as 10 miles from the intended drop area, to the SW of ground zero (References 17, 18). Five paratroops were slightly injured on landing. The rest of the paratroops jumped as scheduled and, by 1120 hours, were either in descent or just reaching the ground (Reference 13). After landing, they proceeded south toward the display area, while the other maneuver troops were proceeding to the north along the same line. At about 1220 hours, approximately 600 yards from ground zero, the two elements would have met. They then would have marched back to the display area and from there to parking area F, where they would have arrived at about 1320 hours. Before leaving the parking area, all personnel were monitored to ensure compliance with radiation limits. The observers and maneuver units left by motor convoy for Camp Desert Rock at about 1330 hours, arriving by 1530 hours.

2.4.2 Shot Dog.

Approximately 350 Navy and Marine Corps personnel were present at Shot Dog as observers (Reference 6). Most reported to Camp Desert Rock between 24 April and 28 April (Reference 13).

Two Marine Corps provisional battalions, totaling about 1,950 troops, also participated at Shot Dog (Reference 9). The 1st Provisional Marine Battalion, from Camp Pendleton, California, arrived on 23 April (Reference 13). It was made up as follows:

	<u>Provided by</u>
H&S Co	Force Troops
Medical and Clearing Platoon	3rd Marine Division
Weapons Co	Force Troops
Rifle Co	3rd Marine Division
Weapons Co	3rd Marine Division
Rifle Co	AirFMFPac
Total planned strength: 1000 (estimated)	
(Reference 19)	

The 2nd Provisional Marine Battalion from Camp Lejeune, North Carolina, arrived on 24 April (Reference 13). It was made up as follows:

		<u>Off</u>	<u>EM</u>
H & S/Co, InfBn (Prov)	Force Troops	12	116
Bn Augmentation	FMFLant		
MedSec	2dMarDiv		
Clr Plat, Coll&ClrngCo	2dMarDiv		
Rifle Co (Prov)	2dMarDiv	7	221
Rifle Co (Prov)	2dMarDiv	7	221
Rifle Co (-1 Plat)(Prov)	Force Troops	6	177
Rifle Co (-1 Plat)(Prov)	AirFMFLant	6	177
TOTALS		<u>38</u>	<u>912</u>

(Reference 5)

The observers, together with the two battalions, were formed into a Marine Corps Provisional Exercise Unit for Shot Dog. In the days between their arrival and the shot, troops participated in pre-shot orientation, including lectures and a full rehearsal of shot-day activities on 27 April (Reference 19). At 0633* hours on shot day, the troops left Camp Desert Rock by motor convoy. They arrived in the trench area at about 0820 hours (Reference 19). Shortly thereafter, a Camp Desert Rock instructor began briefing the troops on shot-time procedures. Ten minutes before the shot, the troops entered the trenches and foxholes (Reference 20), 7000 yards south of ground zero (see Figure 3). The 1st Provisional Battalion was on the right and the 2nd Provisional Battalion was on the left (Reference 21). Observers were likely in the center with the control element. Two minutes before the shot, all personnel crouched down in the trenches. The shot went off at 0930 hours as scheduled. Three seconds after the flash, the troops were permitted to stand in the trenches to observe the rising fireball (Reference 20). The reference also states that, with the passage of the blast wave, maneuver personnel left their cover and moved forward as if jumping off in the attack. This movement did not continue; the major forward movement was by truck. Immediately following the shot, the Marine Corps radiological safety party accompanied the Camp Desert Rock radiological parties on the initial survey of the display area. At 1051 hours, R-hour was declared by the AEC. Thirty minutes later, all personnel traveled by truck convoy to parking area F, where they

*All times for Shot Dog are Pacific Daylight Time.

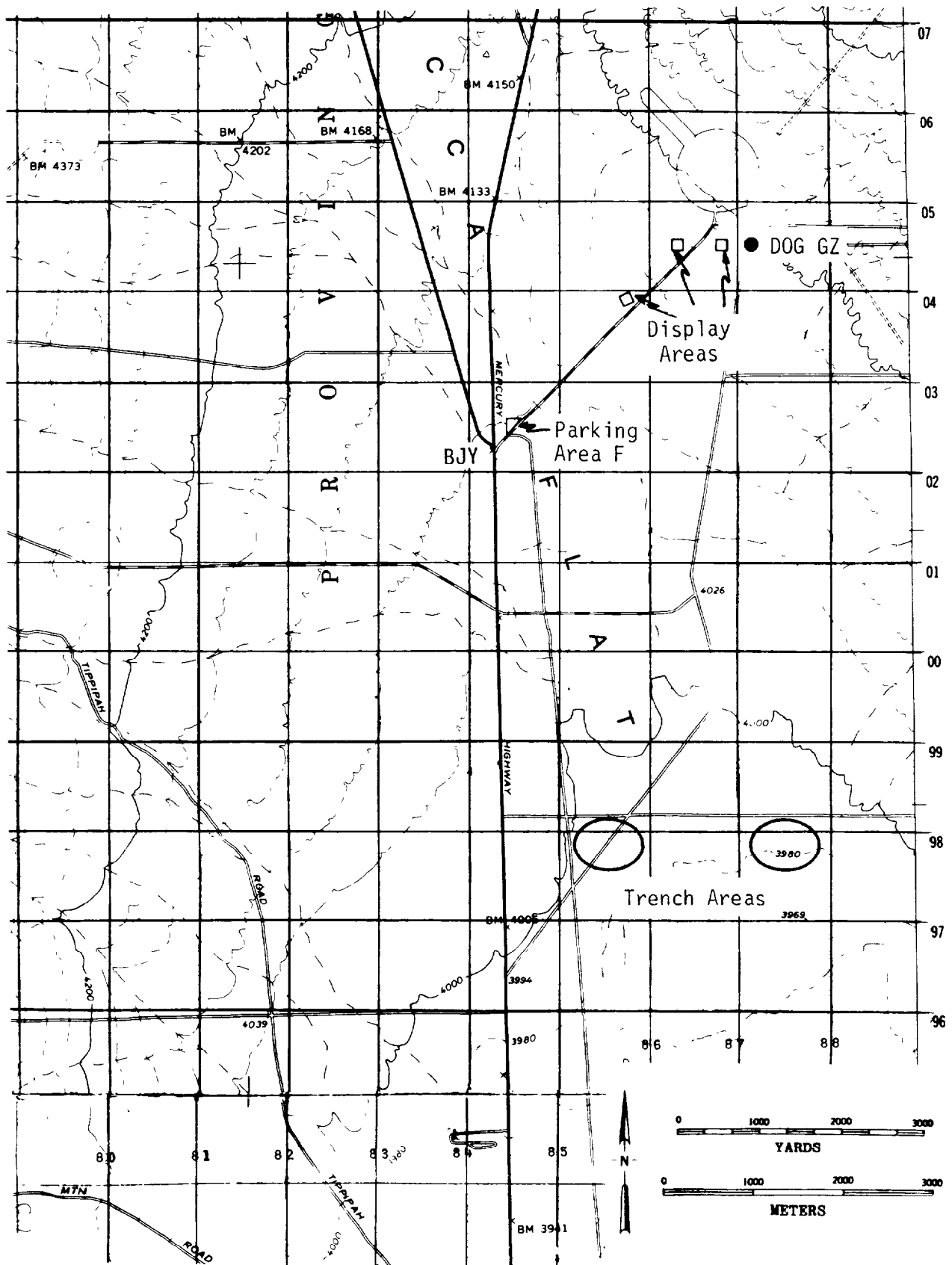


Figure 3. Shot Dog area.

arrived about twenty minutes later. At about 1150 hours, the troops began their tour of the equipment display areas, located 1700-1750, 900-1000, and 300- 400 yards from ground zero (see Figure 3). A "special position" at 1300 yards contained only dummies clad in uniforms (Reference 21). The troops advanced to the first two areas and stopped at each to view the effects of the explosion on the equipment. Near the 900-yard display, the troops would have reached the 500 mr/hr level, the usual limit for forward advance. Evidently, they were permitted to proceed closer to GZ, as Reference 20 states that "the radiation intensity at position 1, that nearest ground zero, was such that a decision was made not to enter the position but view it from a distance of about 100-200 yards." At this distance from the outermost displays of position 1, personnel would have been 500-600 yards from ground zero.

After halting their advance, the troops returned to the parking area, where they arrived at about 1345 hours (References 20, 21). References 20 and 19 state that, upon return to the parking area, each individual was monitored and, as all readings were well below the prescribed 10 mr/hr, motor serials were dispatched for the return to Camp Desert Rock as soon as they were loaded. The troops probably arrived at Camp Desert Rock at about 1530 hours (References 20, 21). Film badges were collected on return. Troops returned to their home units on 2 May (Reference 19).

2.4.3 Shot Fox.

Exercise Desert Rock IV participation at Shot Fox consisted of approximately 500 observers from the six continental armies and service schools, and approximately 950 observers from the 701st Armored Infantry Battalion (AIB), First Armored Division, Fort Hood, Texas (including Companies A, B, C, and D) (References 1, 6, 9, and 22). There was no tactical maneuver at Shot Fox (Reference 23).

Shot Fox was originally scheduled to be detonated on 13 May, but due to poor weather conditions and a 20 May misfire, the detonation did not occur until 25 May. The 701st AIB, which was planning to participate in the rescheduled Shot George, arrived at Camp Desert Rock on 22 May. On 23 May, the Office of Chief of Army Field Forces directed that the 701st AIB participate in Shot Fox instead of the 369th

Engineer Amphibious Support Regiment, the unit originally scheduled for participation at Shot Fox. This was probably done to minimize the time that the 701st spent at Camp Desert Rock waiting for a shot. The 369th, being a Camp Desert Rock support unit, could conveniently participate in either shot. The 369th EASR participated in Shot George instead (Reference 6).

All observers at Shot Fox participated in the same activities and are treated as a single unit. On 23 May, the observers attended four hours of lectures probably covering nuclear weapons effects, protective measures, and the plan for the shot. On 24 May, the observers participated in a rehearsal of shot day activities. They left Camp Desert Rock at 1220 hours* and probably arrived in the entrenchment area, 7000 yards southeast of ground zero, at about 1400 hours (see Figure 4). While in the trench area, they were briefed on what to expect on shot day; they then practiced entering the trenches and taking protective measures during a simulated burst. At about 1530 hours, the troops inspected the equipment display areas to view their pre-shot condition (Reference 22).

On shot day, the observers left Camp Desert Rock by motor convoy at 0150 hours, arriving in the trench area at about 0320 hours. About an hour before the shot, Camp Desert Rock instructors briefed the troops. At 0450 hours, the troops entered the trenches. Two minutes before the shot, the troops were ordered to crouch and lean against the forward trench wall. The detonation occurred at 0500 hours as scheduled. Five seconds after the detonation the troops were permitted to stand in the trenches and observe the rising nuclear cloud (Reference 22). Twenty seconds after the detonation, the shock wave passed over the observer trenches (Reference 24). The monitors immediately advanced to survey the shot area (Reference 16). R-hour was declared at about 0720 hours (Reference 22).

At 0730 hours, the observers loaded into trucks and traveled in convoy to parking area K, where they arrived at about 0805 hours. Their route took them north past BJY, then west to the parking area. The observers detrucked at about 0815 hours to

*All times for Shot Fox are Pacific Daylight Time.

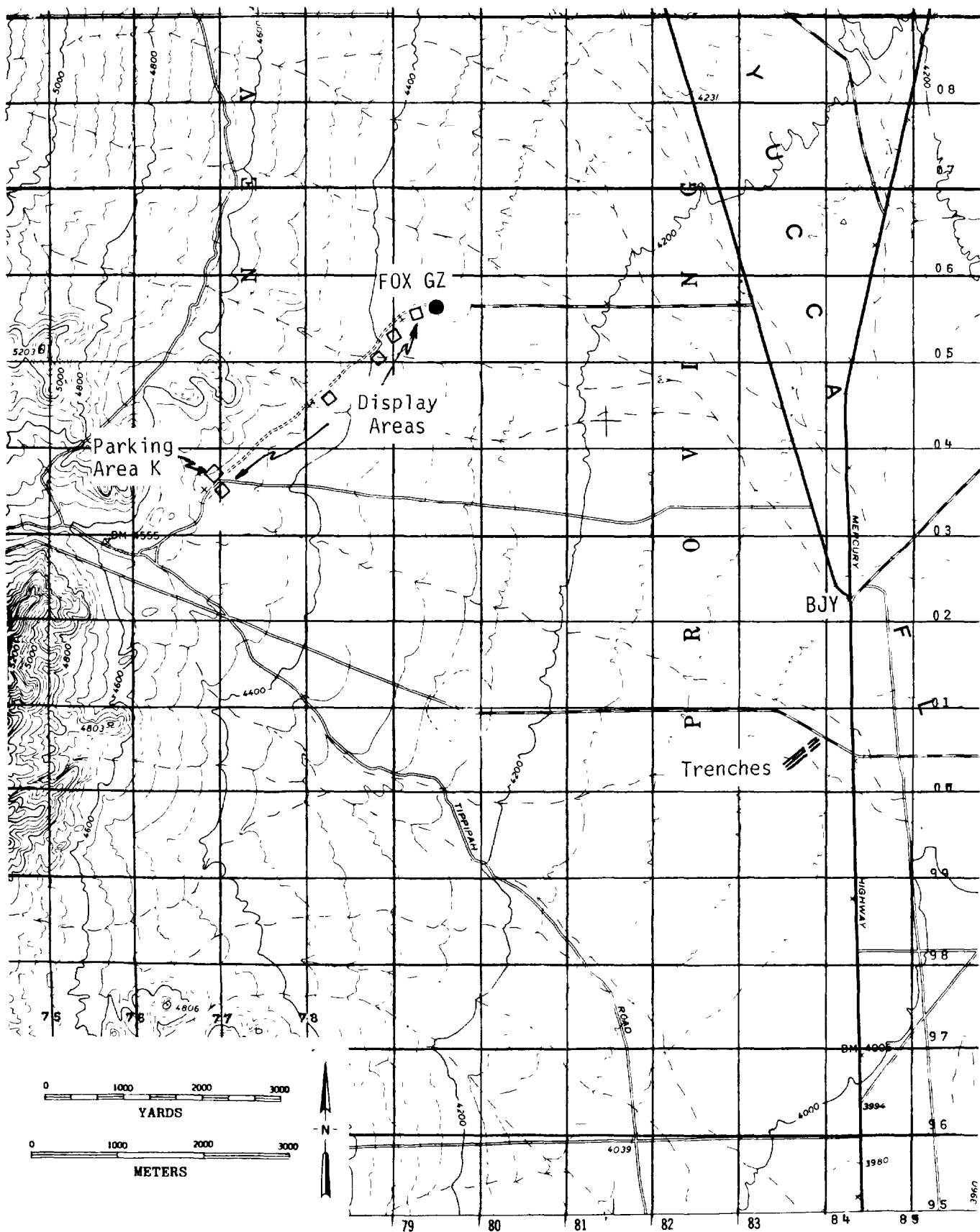


Figure 4. Shot Fox area.

begin their inspection of the equipment displays located 3500, 1700, 900, 550, and 200 yards from ground zero, to the extent consistent with rad-safe criteria (References 1 and 22). The observers then returned to their vehicles at the parking area, at about 1020 hours (Reference 1). Before leaving for Camp Desert Rock, all personnel and vehicles were monitored for contamination. The troops departed parking area K by motor convoy at about 1100 hours, arriving at Camp Desert Rock at about 1300 hours.

2.4.4 Shot George.

Observers. Original plans called for Shot George to be detonated in Area 2, but residual radioactivity from Shots Easy and Fox delayed preparation of the area. Consequently, the Test Manager decided to detonate George in Area 3 and use Area 2 for Shot How (Reference 24).

Observers for Shot George consisted of 450-650 personnel from the six continental armies and military service schools (References 1, 7). Most observers arrived at Camp Desert Rock between 16 and 19 May. All observers took part in the same orientation and training activities (Reference 24).

The week before the detonation, the observers rehearsed their shot-day activities, including an inspection of the equipment display area (Reference 24). On shot day, the observers left Camp Desert Rock at 0220 hours* by motor convoy and arrived in the trench area 7000 yards south of GZ before 0400 hours (Figure 5). For the next hour, Camp Desert Rock instructors briefed the troops on shot-time procedures. Both the observers and maneuver troops occupied the same set of trenches (Reference 1). Two minutes before the shot, the instructor ordered all personnel to crouch, cover their faces with their hands, lean against the forward trench wall, and remain below ground level until after the detonation. The shot was detonated on schedule at 0455 hours. Three seconds after the flash, the troops were allowed to stand and observe the

*All times for Shot George are Pacific Daylight Time.

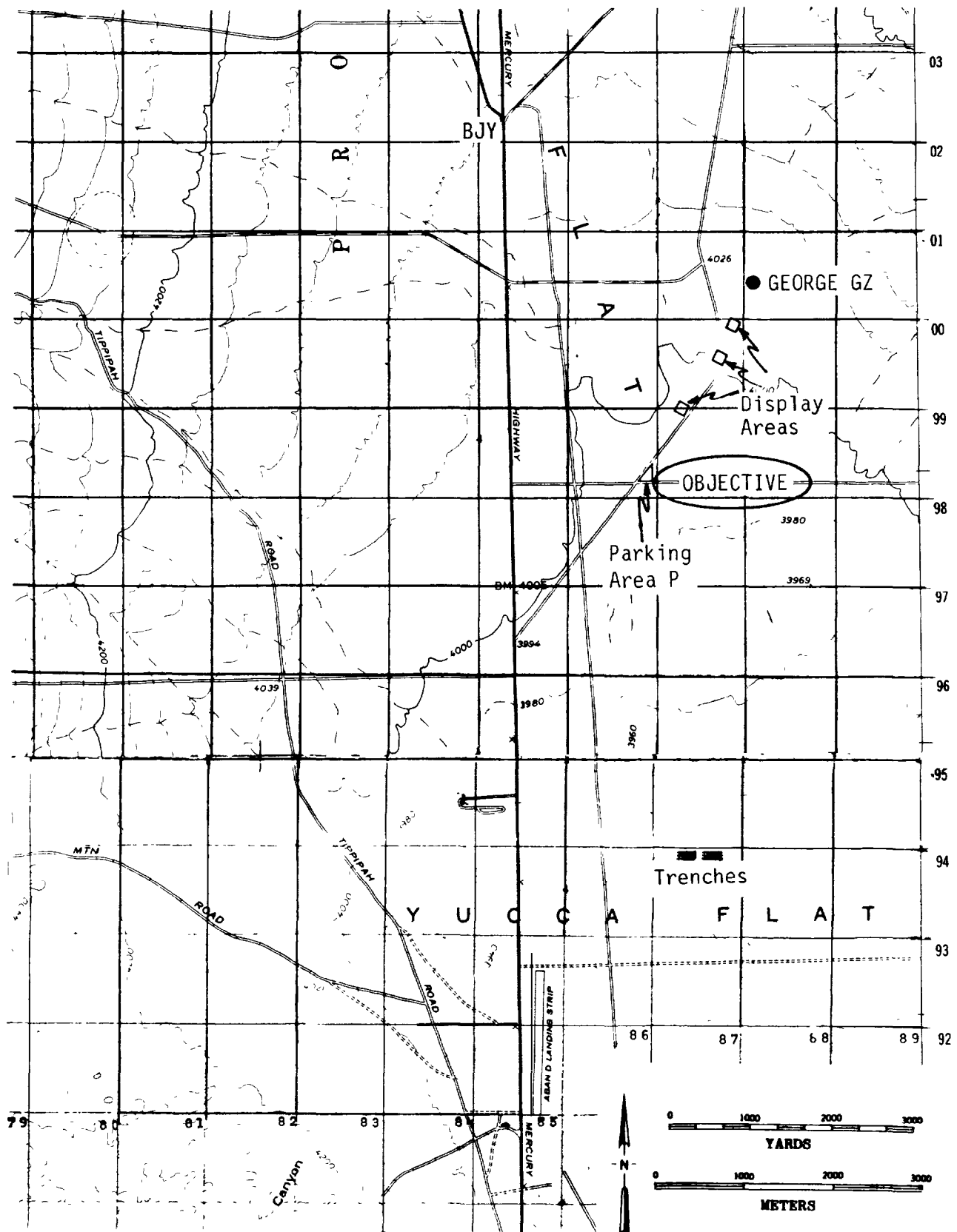


Figure 5. Shot George area.

rising fireball (Reference 24). About 20 seconds after the shot, the shock wave reached the trench area (Reference 24). Immediately after the shot, Army monitors moved forward to survey the contaminated area and mark the 500 mr/hr line, the limit of advance. Recovery hour was declared at 0705 hours (Reference 15). At 0710 hours, the observers left the trench area by motor convoy for parking area P, where they arrived about 30 minutes later. They began their walk-through of the equipment display areas at about 0750 hours. The equipment displays were located 1700, 900, 550, and 500 yards from ground zero. Fabric and clothing samples were located 1800 and 2800 yards from ground zero (Reference 1). The troops stopped at each display that they got to and observed the effects of the detonation on the equipment. Due to radiation intensities, the 900-yard display area was the closest that troops were able to approach to GZ. After viewing this display area, the observers returned to parking area P, where all personnel and vehicles were monitored for contamination before departure. The observers departed parking area P by motor convoy at about 0940 for Camp Desert Rock, where they arrived at 1100.

Maneuver Units. Maneuver units for Shot George consisted of:

369th Engineer Amphibious Support Regiment (minus Boat Battalion)

Headquarters and Service Company

Headquarters and Headquarters Company, Shore Battalion

Companies D, E, and F

31st Transportation Truck Company

Tank Platoon, First Armored Division

(References 1, 9, and 10)

Approximately 1400 troops participated in the maneuver (References 1 and 7). In the days preceding the shot, Camp Desert Rock instructors presented an indoctrination of nuclear weapons effects, protective measures, and the plan for shot day. The week before the shot, the troops rehearsed their shot day activities.

On shot day, the maneuver units left Camp Desert Rock by motor convoy at about 0155 hours. They arrived in the trench area two hours later (Reference 1). Until they began their post-shot maneuver, the maneuver troops followed the same scenario as the observers, except that tank crews remained inside their tanks, near the

trenches, for the detonation. Because of the proficiency demonstrated by Army radiation monitors at previous shots, Desert Rock commanders were authorized to commence maneuvers immediately after the shock wave, with monitors to ensure radiological safety, rather than wait for the usual declaration of R-hour by the AEC (References 1 and 7). The maneuver units on foot were led by five tanks and followed by the vehicles that had brought them to the trench area (Reference 1). The troops reached their objective (see Figure 5) and, as radiation levels were low there, continued their advance. The tanks, however, are judged to have followed the original plan and turned left at the objective to proceed to parking area P. Due to the sensitivity of the display and scientific experimental areas, any deviation from the planned movement would almost certainly have not been permitted for the tanks. At about 0645 hours, the troops reached a radiation intensity of 500 mr/hr, the limit for forward advance (References 1 and 7). The troops moved laterally to the 900-yard equipment display area, arriving there at about 0655 hours (Reference 20). After viewing the effects of the detonation on the equipment, the troops moved to the 1700-yard equipment display. They then moved to parking area P, where the trucks were waiting, arriving there at about 0745. All personnel and vehicles were then monitored. The troops departed parking area P at about 0815 by motor convoy, arriving at Camp Desert Rock at about 0940.

SECTION 3

INITIAL RADIATION

No military personnel were located closer than 7,000 yards from any detonation. Previous calculations have established that, for the type of devices detonated at Operation Tumbler-Snapper, there would have been a negligible (less than 0.001 rem) initial dose for personnel at this distance, whether in trenches or in the open (Reference 25).

SECTION 4

RESIDUAL RADIATION

4.1 RESIDUAL GAMMA EXPOSURE.

External gamma doses are reconstructed for observers and maneuver troops, based on their activities in the fallout and neutron-induced activity fields of Shots Charlie, Dog, Fox, and George. A computerized methodology, described in Reference 2, determines the radiological environment for each shot of interest. From this, doses are calculated based on the scenario of activities. Iso-intensity contours with superimposed troop tracks are displayed for each shot.

The computer-calculated doses do not reflect the presence of the human body in the radiological environment. Despite the penetrating ability of gamma rays from fission and activation products, the body affords some shielding; hence, the gamma dose to any organ depends on the geometry of the radiation source and the body position. In order to represent reconstructed film badge readings, gamma doses are calculated for the surface of the chest, where a film badge is normally worn. The calculated film badge dose rate is related to the free-field gamma intensity through the conversion factor developed in Reference 26: 1 R/hr \rightarrow 0.7 rem/hr.

Observer dose calculations are categorized by the shot in which each observer group participated. Contributions from previous shots to the dose are noted as they arise.

Because of limited data concerning the details of display inspection and the timing involved, estimates are required for various parameters. Rates of movement are estimated from planned times or the few reported times, the number of displays viewed, the calculated or reported position of radiological safety limits, and the consequent distance to be traversed. A reasonable and consistent set of parameters is 50 yds/min walking speed between displays (including the starting and stopping of troops), 5 minutes at each display and at the limit of march toward GZ, and 70 yds/min on the return. Speeds for motor movements are taken from the operation plans or estimated from road conditions and vehicle type.

4.1.1 Shot Charlie.

The Charlie residual radiation contours are nearly circular and symmetric, typical of the neutron-induced activity of a high air burst. The radiation intensities were very low--the closest contour shown in Figure 6 represents the 10 mr/hr level. Therefore, rad-safe criteria played no constraining role in post-shot activities. Based on the scenario described in Section 2, it is calculated that the ground troops received a film badge dose of 19 mrem during their movement through the display areas and to the rendezvous point with the paratroops. Because the Charlie cloud drifted out of range before the aircraft took off, the paratroops would have received no dose while in the aircraft or in descent. During their movement to the rendezvous point, the paratroops received a dose of 2 mrem. During their movement together back to the parking area, the maneuver troops received a dose of 9 mrem. Therefore, the ground troops received a total dose of 28 mrem, and the paratroops a total dose of 11 mrem. The observers, moving as described in Section 2, received a dose of 19 mrem.

4.1.2 Shot Dog.

As seen in Figure 7, the radiation contour lines are nearly circular and symmetric, typical of neutron induced activity of an air burst. The maneuver and observer elements advanced together and would have reached the 500 mr/hr line, the usual limit for forward advance, at about 900 yards from ground zero. However, Reference 20 states that troops advanced to within 100-200 yards of the display area nearest ground zero. This would have placed the distance of closest approach at about 500 yards from ground zero, where the radiation intensity would have been about 5 R/hr. Available documentation has indicated the possibility of advancing past 0.5 R/hr if so ordered by the Desert Rock Commanding General (after consulting with rad-safe personnel). Moreover, the 0.5 R/hr intensity restriction may not have applied to the Marine Corps maneuver. In Operation Upshot-Knothole (1953), the Marine Corps maneuver had a limit different from that of other troop activities (Reference 27), but no positive indication of a similar limit for this operation exists in available documentation.

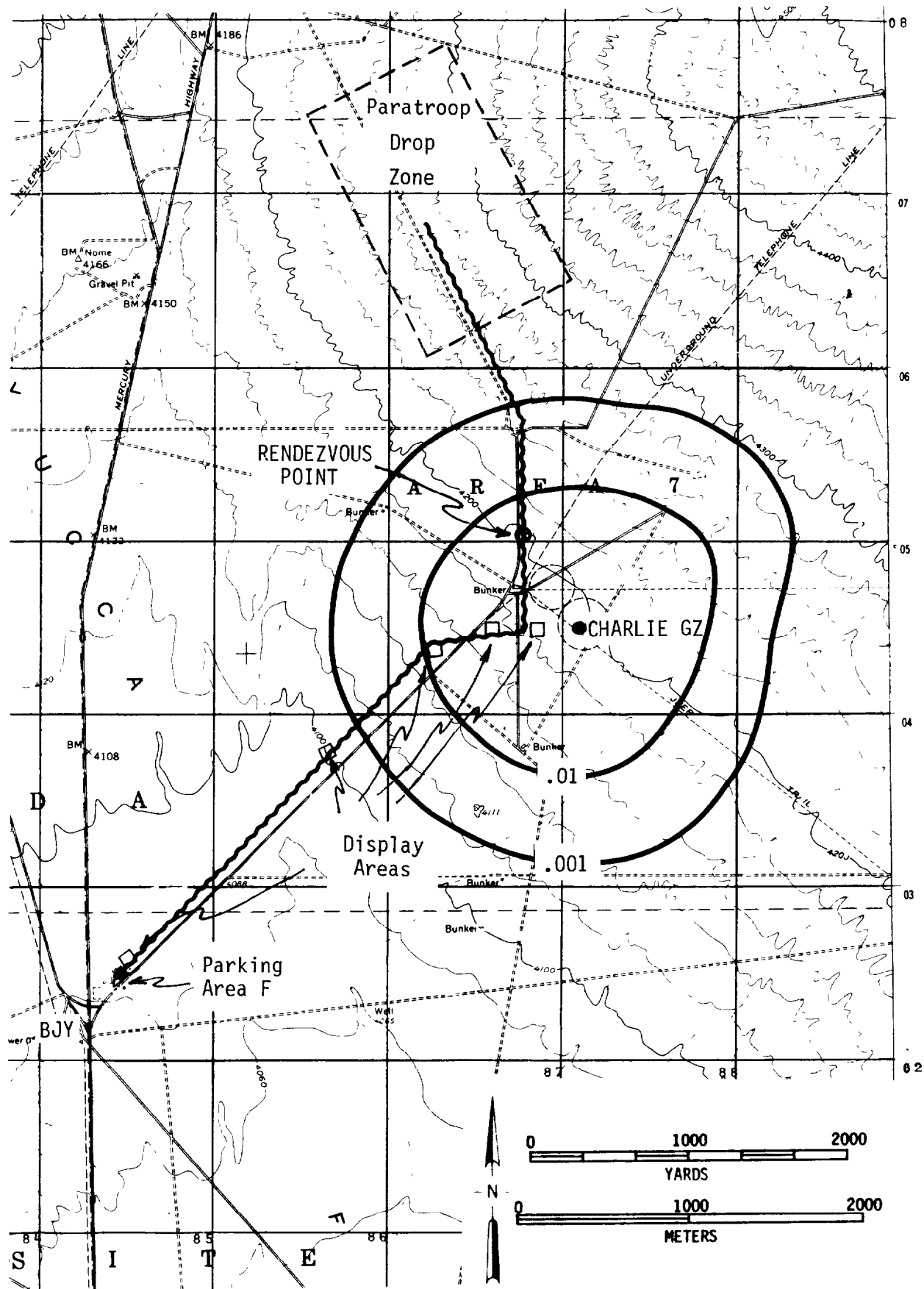
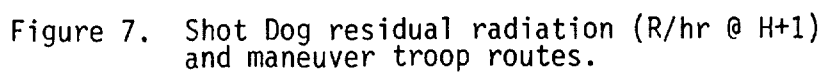


Figure 6. Shot Charlie residual radiation (R/hr @ H+1) and observer and maneuver troop routes.



Based on the foregoing scenario, the residual gamma film badge dose for the forward elements was 370 mrem.

4.1.3 Shot Fox.

Radiation contours for Shot Fox are shown in Figure 8. Calculations show that the troops would have reached the 500 mr/hr line about 100 yards before arriving at the 550-yard equipment display area. However, the intensity at this display would have been less than 800 mr/hr, and it is possible that a decision was made to view the display. In order to consider this possibility, it is assumed that the troops did advance to the 550-yard display. Based on this scenario, Shot Fox participants received a film badge dose of 126 mrem.

4.1.4 Shot George.

Radiation contours for Shot George are shown in Figure 9. It is not clear from the available records whether the maneuver troops stopped their advance at their objective, some 2500 yards south of ground zero, as planned, or continued their advance beyond the objective. The radiation intensity at the objective would have been less than 10 mr/hr. The maneuver troops could have advanced to the 500 mr/hr line, which would have been about 850 yards from GZ, then moved about 500 yards laterally along the isopleth to the 900-yard display area and then the 1700-yard display. Based on this scenario, the calculated film badge dose for the maneuver troops is 106 mrem. The observers, moving as described in Section 2, received a film badge dose of 28 mrem.

4.2 INTERNAL RADIATION EXPOSURE.

While operating in residual radiation fields, participants were subject to an internal dose commitment from the inhalation of airborne radionuclides. The internal dose pathways are resuspension of fresh fallout and suspension of neutron-activated soil while marching. Internal dose commitments for maneuver troops and observers, investigated and reported in Reference 28, are shown to be 150 mrem or less for a 50-year bone dose commitment.

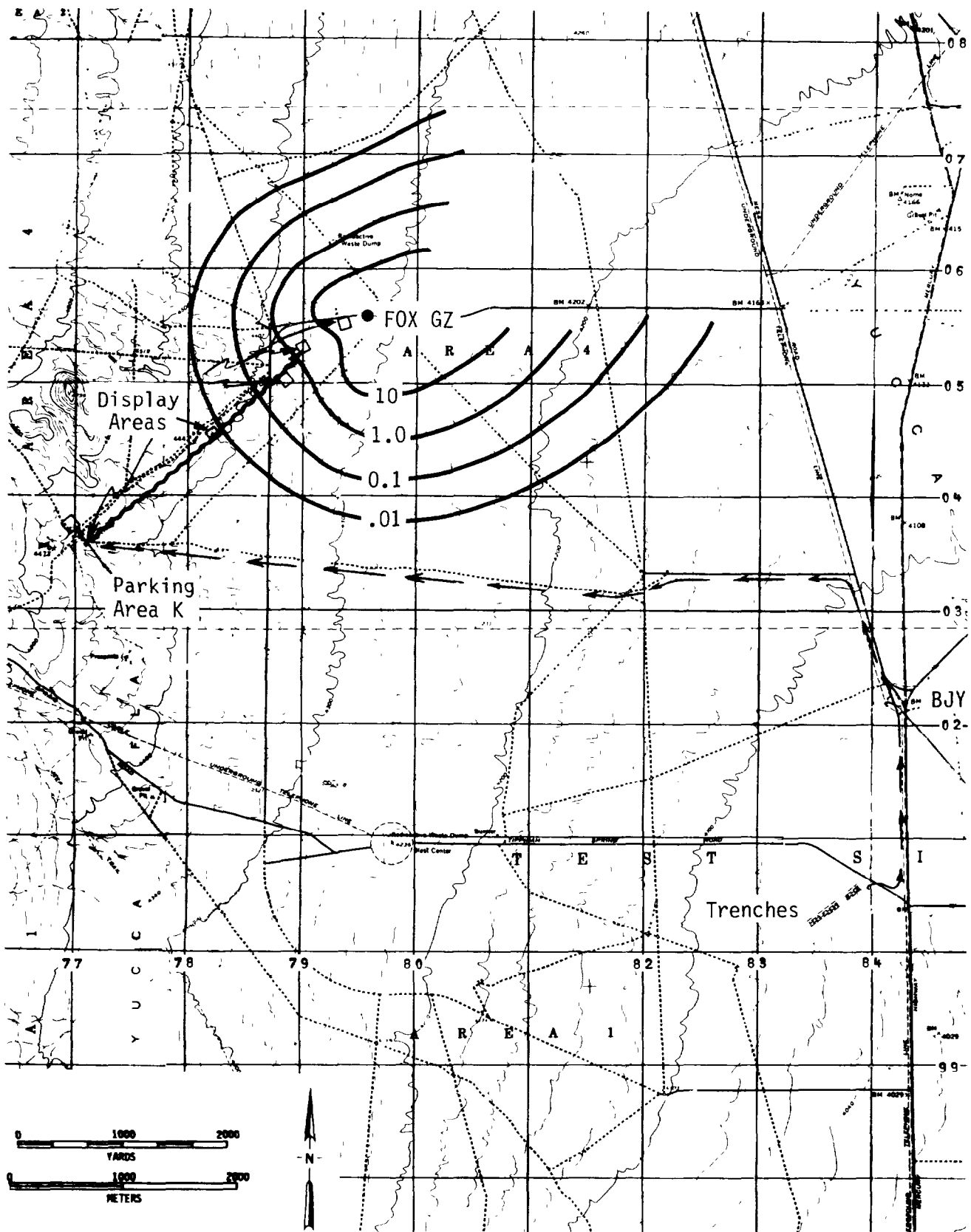


Figure 8. Shot Fox residual radiation (R/hr @ H+1) and observer routes.

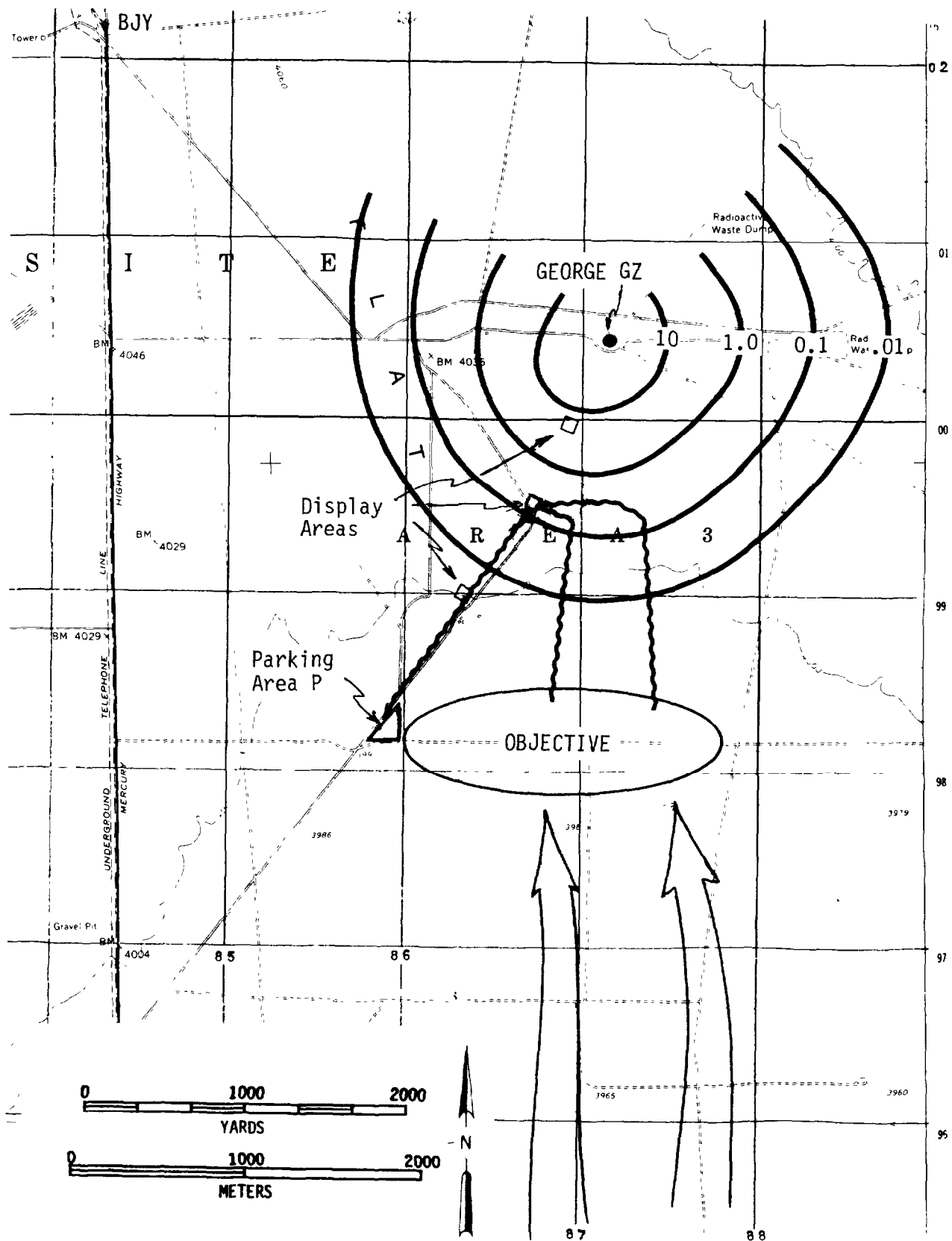


Figure 9. Shot George residual radiation (R/hr @ H+1) and observer and maneuver troop routes.

4.3 RESIDUAL RADIATION DOSE SUMMARY.

The calculated film badge doses (mrem) to Exercise Desert Rock IV personnel are summarized below:

	<u>Shot</u>			
	<u>CHARLIE</u>	<u>DOG</u>	<u>FOX</u>	<u>GEORGE</u>
Observers	19	370	126	28
Ground Maneuver Troops	28	370	N/A	106
Paratroops	11			

SECTION 5

UNCERTAINTY ANALYSIS AND TOTAL DOSE DETERMINATION

The sources of error in the calculation of residual doses are examined in order to quantitatively estimate the uncertainty in the dose for each unit. The approach for quantifying the uncertainty follows that for previous analyses. References 26 and 27 give a more comprehensive treatment of the methodology.

5.1 UNCERTAINTIES IN RESIDUAL RADIATION DOSE.

The uncertainty in calculated residual radiation doses arises from two basic sources: (1) gamma radiation environment, and (2) the space-time scenario of troop movements. The 90-percent confidence limits in the gamma intensity, including the uncertainty in the decay exponent and the time-space variations in troop scenarios, are facilitated through parametric studies using an automated dose determination procedure developed in previous analyses (Reference 2).

In the display areas, the limits of advance were not always reported. When the references do not report which equipment display lines were inspected, the assumption is made that all of the displays within rad-safe limits were inspected. The dose accrued within the display area is usually maximized if the innermost display visited is coincident with the rad-safe limit. Within the uncertainty of the radiation field, this is often a possibility.

The timing of the troops' march is generally based on the planned time of attack, time of arrival at the objective, and arrival at the pickup point. Reasonable march speeds and display area stay times are assumed, in order to construct a scenario consistent with the planned times. The most important influence of timing on the uncertainty in dose is the time spent at the position(s) of greatest gamma intensity. Uncertainties based on timing are high-sided by coupling stay times (all upper limits are considered together) and by ignoring the overall time constraint on the combination of long stay times and slow march speeds.

The various sources of error are combined approximately; they cannot be combined rigorously due to the disparity of their associated distributions. While some distributions are normal as expressed (e.g., a march speed ± 10 yds/min or a halt point ± 100 yards from GZ), they imply a more lognormal distribution in dose. For each source of uncertainty, the limits on dose are interpreted in terms of error factors on the best-estimate doses from Section 4. Uncertainties are combined as for lognormal distributions. The overall uncertainties permit determination of the mean dose from residual radiation for each shot. Only for significantly skewed distributions is the mean much different from the best estimate. For multiple exposures, the means may be legitimately added to find the mean total dose, which may be compared to film badge data or entered as an individual's assigned gamma dose. Ninety-percent confidence limits are estimated for each calculated dose.

5.1.1 Shot Charlie.

Paratroops. Uncertainty in the residual radiation dose for Shot Charlie Paratroop units stems from two sources: (1) the residual radiation field and (2) marching speeds. The marching speed for the paratroops was taken to be 70 ± 10 yds/min. The calculated film badge doses, with uncertainties, are:

<u>Source of Uncertainty</u>		
<u>Residual</u> <u>Field</u>	<u>March</u> <u>Speeds</u>	<u>Combined</u>
$11 \begin{smallmatrix} +2 \\ -2 \end{smallmatrix}$	$11 \begin{smallmatrix} +2 \\ -2 \end{smallmatrix}$	$11 \begin{smallmatrix} +3 \\ -2 \end{smallmatrix}$

Ground Troops. Uncertainty in the residual radiation dose for Shot Charlie maneuver units stems from three sources: (1) the residual radiation field, (2) marching speeds, and (3) stay times at the equipment display areas. Marching speeds were taken to be 50 ± 10 yds/min while marching between the display areas, and 70 ± 10 yds/min while marching to meet the paratroops and on return to the parking area. Stay times were taken to be five minutes with a factor of two variation. The calculated film badge doses, with uncertainties, are:

Source of Uncertainty

<u>Residual Field</u>	<u>March Speed</u>	<u>Stay Times</u>	<u>Combined</u>
28 $\begin{smallmatrix} +7 \\ -5 \end{smallmatrix}$	28 $\begin{smallmatrix} +10 \\ -8 \end{smallmatrix}$	28 $\begin{smallmatrix} +12 \\ -8 \end{smallmatrix}$	28 $\begin{smallmatrix} +17 \\ -11 \end{smallmatrix}$

Observers. Uncertainty in residual radiation dose for Shot Charlie observers is due to the three same sources as for the maneuver troops. The calculated film badge doses, with uncertainties, are:

19 $\begin{smallmatrix} +4 \\ -3 \end{smallmatrix}$	19 $\begin{smallmatrix} +2 \\ -2 \end{smallmatrix}$	19 $\begin{smallmatrix} +8 \\ -6 \end{smallmatrix}$	19 $\begin{smallmatrix} +10 \\ -6 \end{smallmatrix}$
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5.1.2 Shot Dog.

The main sources in uncertainty for Shot Dog are (1) the distance of closest approach to GZ, (2) marching speeds, and (3) the radiation field intensity. Based on available references, the distance of closest approach could be uncertain by as much as 100 yards--if the troops reached only 200 yards from the outermost display or 100 yards from the innermost display of position 1. Therefore, a distance of closest approach of $500 \begin{smallmatrix} +100 \\ -100 \end{smallmatrix}$ yards was used. Marching speeds of $50 \begin{smallmatrix} +10 \\ -10 \end{smallmatrix}$ yds/min and $70 \begin{smallmatrix} +10 \\ -10 \end{smallmatrix}$ yds/min were used in the calculation. The computer construction provides upper and lower limits due to uncertainty in radiation intensities. Since most of the dose was accrued near the point of closest approach, stay times had little effect on total uncertainty. The calculated film badge doses, with uncertainties, are:

Source of Uncertainty

<u>Distance of Closest Approach</u>	<u>March Speeds</u>	<u>Residual Field</u>	<u>Combined</u>
370 $\begin{smallmatrix} +240 \\ -140 \end{smallmatrix}$	370 $\begin{smallmatrix} +60 \\ -50 \end{smallmatrix}$	370 $\begin{smallmatrix} +50 \\ -50 \end{smallmatrix}$	370 $\begin{smallmatrix} +260 \\ -150 \end{smallmatrix}$

5.1.3 Shot Fox.

Uncertainty in the residual radiation dose for Shot Fox stems from two sources: (1) time spent at the display areas, and (2) the reconstructed radiation contours. Stay times are assumed to be 5 minutes, with an error factor of 2. Most of the dose was accumulated at or near the 550-yard display area; thus march speeds and timing of activities contribute negligibly to overall uncertainty. March speeds were assumed to be 50 ± 10 yds/min during approach to GZ and 70 ± 10 yds/min during the return to the parking area. The calculated film badge doses, with errors, are:

<u>Source of Uncertainty</u>		
<u>Stay Times</u>	<u>Residual Field</u>	<u>Combined</u>
126 $\begin{smallmatrix} +47 \\ -34 \end{smallmatrix}$	126 $\begin{smallmatrix} +23 \\ -19 \end{smallmatrix}$	126 $\begin{smallmatrix} +54 \\ -38 \end{smallmatrix}$

5.1.4 Shot George.

Observers. The sources of uncertainty in dose reconstruction for the observers are from (1) the residual field intensity and (2) stay time at the 900-yard equipment display area. A stay time of five minutes was used for the computer reconstruction, but a stay time of as long as ten minutes is used for the 90-percent confidence limit. Uncertainty in other stay times, marching speeds, and activity times contribute negligibly to overall uncertainty. The calculated film badge doses, with uncertainties are:

<u>Source of Uncertainty</u>		
<u>Residual Field</u>	<u>Stay Times</u>	<u>Combined</u>
28 $\begin{smallmatrix} +16 \\ -10 \end{smallmatrix}$	28 $\begin{smallmatrix} +11 \\ -8 \end{smallmatrix}$	28 $\begin{smallmatrix} +20 \\ -12 \end{smallmatrix}$

Maneuvers. Sources of uncertainty in the dose reconstruction for the maneuver troops are due to: (1) the residual field intensity, (2) stay time at the 900 yard display area, and (3) distance moved laterally along the 500 mr/hr line. A stay time of 10 minutes was used for the 90-percent confidence limit. The distance the troops moved laterally along the 500 mr/hr line was given in Section 4 as about 500 yards, but due to uncertainty in the exact route of advance towards GZ, this distance could have varied by ± 100 yards. The calculated film badge doses, with uncertainties, are:

Source of Uncertainty

<u>Residual</u> <u>Field</u>	<u>Stay</u> <u>Times</u>	Distance Marched along 500 mr/hr <u>Line</u>	<u>Combined</u>
106 $\begin{smallmatrix} +85 \\ -47 \end{smallmatrix}$	106 $\begin{smallmatrix} +16 \\ -14 \end{smallmatrix}$	106 $\begin{smallmatrix} +14 \\ -12 \end{smallmatrix}$	106 $\begin{smallmatrix} +88 \\ -50 \end{smallmatrix}$

5.2 TOTAL DOSE SUMMARY.

The reconstructed gamma doses for Exercise Desert Rock IV units are presented in Table 4. From the best-estimate doses of Section 4 and the error distributions of Section 5, the mean gamma dose for each unit is calculated. These are presented along with estimated 90-percent confidence limits.

Table 4. Dose summary, Operation Tumbler-Snapper.

<u>Shot</u>	<u>Unit</u>	<u>Total Dose (rem)</u>
CHARLIE	Paratroops	0.011 $^{+.003}_{-.002}$
	Ground troops	0.028 $^{+.020}_{-.010}$
	Observers	0.019 $^{+.010}_{-.006}$
DOG	Maneuver troops	0.370 $^{+.260}_{-.150}$
FOX	Observers	0.130 $^{+.050}_{-.040}$
GEORGE	Maneuver troops	0.110 $^{+.090}_{-.050}$
	Observers	0.028 $^{+.020}_{-.010}$

SECTION 6

FILM BADGE DOSIMETRY

Film badge records for Operation Tumbler-Snapper are available from a film badge list for Shots Fox and George. For Shot Dog, the only indication of exposure is a statement in Reference 6 that integrated doses were less than 500 mrem for most personnel. No other records of exposure are available.

For Shot Fox, 104 records are available. It is not known to which Shot Fox units these records pertain. Aside from six outliers, the badges appear to have a bimodal distribution. One group of 10 badges has a mean of 107 mrem and standard deviation of 31 mrem, which compares very well with the reconstructed dose of 130^{+50}_{-40} mrem. The second group consists of 88 badges with a mean of 303 mrem and a standard deviation of 51 mrem. The highest reading (isolated) of any Shot Fox film badge was 840 mrem. It is possible that these badges represent undocumented activities of other Shot Fox participants. It is noted that the 104 film badge records available for Shot Fox are a very small sample, with unknown representativeness, of the estimated 1450 observers, and that there are no badges for the largest participating unit, the 701st AIB. However, all film badges indicated exposures significantly less than the maximum permitted dose of 3 rem.

For Shot George, 238 records are available. The badges have a mean dose of 156 mrem and a standard deviation of 27 mrem. The highest reading (one of 9 outliers) was 300 mrem. The calculated film badge dose of 106^{+87}_{-48} mrem compares well with the actual film badge doses, particularly when the distribution of badge readings is compared with the confidence range of the calculated doses. Reference 6 indicates that the average exposure for this shot was less than 500 mrem.

SECTION 7

CONCLUSIONS

Exercise Desert Rock IV personnel participated in four of the eight test shots of Operation Tumbler-Snapper. No personnel were located closer than 7000 yards from ground zero at the time of the detonations. Moreover, all personnel were in trenches or had similar protection.

Initial radiation dose was insignificant for all participants, due to the large distance from the shot.

Residual radiation doses were very low, ranging from 0.011 rem (Shot Charlie, paratroop unit) to 0.37 rem (Shot Dog participants).

The 50-year bone dose commitment for inhaled radionuclides was determined in Reference 28 to be 0.15 rem or less for all participants.

Calculated doses for all observers and maneuver troops were far less than the maximum allowable dose of 3 rem.

In general, available film badge data correlates well with the calculated gamma doses.

SECTION 8

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***Not available, see Availability Information page following.

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28. "Low Level Internal Dose Screen, Nuclear Test Personnel Review," Volume I, CONUS Tests, DNA-TR-85-317-V1, Defense Nuclear Agency, 10 October 1985.

* Available from NTIS; order number appears before the asterisk.

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